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SAFETY ELECTRIC SWITCHES FOR MINES

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ENGIN STORAGE

BY

H. H. CLARK

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SAFETY ELECTRIC SWITCHES FOR MINES.

By H. H. Clark.

INTRODUCTION.

As a part of its investigation into the causes of mine accidents and the safeguarding of the use of electricity underground, the Bureau of Mines has recently completed a preliminary study of electric switches designed to prevent the ignition of gas by the spark that is drawn when such a switch is operated under load.

The purpose of this investigation was to study the various means and methods used to confine the flashes that occur when such switches are operated. When a 250-volt direct-current circuit, carrying more than one-half ampere, is opened, the resulting flash will ignite explosive mixtures of gas and air. An equally dangerous flash may be produced by less current from a 500-volt circuit. Few mine electric circuits carry less than half an ampere when in use. The need of protecting the switches of such circuits in places where gas is likely to be present is therefore obvious.

The following brief review of the test results is published in advance of a more detailed description, which will appear in another report.

TYPES OF SWITCHES.

Two general methods have been proposed to prevent switching flashes from coming in contact with gas that surrounds the switch. One method is to inclose the switch in a casing provided with openings that are covered with gauze or are otherwise designed and equipped, so that if a gas explosion occurs inside the casing the flames will be extinguished before they can reach the gas outside. Switches so protected are called explosion-proof switches. The other method is to immerse the switch contacts in oil to such a depth that the flash can not reach the explosive mixture. Switches so protected are called oil-type switches.

COMPARISON OF THE TWO TYPES.

The success of the first-mentioned method of protection depends on the proper design and construction of the switch casing. The merit of such design and construction can be determined by test.

The successful operation of the second-mentioned method is dependent on the switch contacts being surrounded by the proper kind of oil in good condition. There are several ways in which the switch may lose its protective feature. The filling of the oil tank may be omitted, or, if it is filled, the oil may leak out or be spilled. The oil tank may be removed (some designs providing for removal) and not replaced, or through neglect the oil may be in such condition that it is no longer an efficient protection. Although it may be considered that such contingencies are not likely to occur, and although it is true that switches may be so designed that the loss of oil is not probable, yet, as compared to oil-type switches, explosion-proof type switches seem to possess a greater element of safety because their protective features are inherent in their construction, and hence if the construction of the switches is suitably rugged the protective features are not likely to be missing or impaired when needed. Moreover, switches of the explosion-proof type can be so designed that the condition of their protective features may be readily examined each time that the switches are operated.

CLASSIFICATION OF SWITCHES TESTED.

The switches tested, were for the purposes of this investigation, divided into two general types according to the construction of the switch and the principle of the safety features. Switches protected by explosion-proof devices were termed type X switches and switches protected by submerging the contacts in oil were termed type O switches.

One automatic and four nonautomatic type O switches and one automatic and one nonautomatic type X switch were tested. Four of the type O switches were rated 100 amperes and one was rated 50 amperes. The automatic type X switch was rated 40 amperes and the nonautomatic type X switch 100 amperes.

TYPE X SWITCHES.

METHOD AND CONDITIONS OF TEST.

All tests were made with direct current from a 200-k. w., 225-volt generator. The switch casings were filled and surrounded with the most explosive mixture of natural gas [a] and air, after which the mixture within the switch casing was ignited by opening the switch under load, and the effect of the ignition upon the gas surrounding the switch casing was noted. The nonautomatic switch was opened by hand. The automatic switch was connected directly across the terminals of the testing generator and in series with a resistance of 1 ohm.

[a] Natural gas from the Pittsburgh city mains was used in these tests; it contains about 83.1 per cent methane, 16.0 per cent ethane, 0.9 per cent nitrogen, and a trace of carbon dioxide. The most explosive mixture of this natural gas and air contains 8.6 per cent gas.

RESULTS OF TESTS.

The protective devices of the nonautomatic switch failed to prevent the passage of flames from the interior to the exterior of the switch casing. This failure was due principally to insufficient area of relief openings and improper spacing of material used. The maximum pressure developed within the switch casing was 20.6 pounds per square inch.

The protection of the automatic type X switch was adequate as far as preventing the passage of flame was concerned, but the safety devices were not sufficiently protected from mechanical injury. The relief areas were large compared to the free inclosed space, and the maximum pressure developed was only 6 pounds per square inch.

TYPE O SWITCHES.

METHOD AND CONDITIONS OF TEST.

All tests were made with direct current from a 200-k. w., 225-volt generator. Each switch was surrounded by the most explosive mixture of natural gas and air and was operated under load 8 to 12 times a minute until the surrounding gas was ignited or until the switch had been operated at least 28,000 times. During this test the oil was not changed. The nonautomatic switches were opened by mechanical means. The automatic switch was connected directly across the terminals of the testing generator and in series with a resistance of 0.37 of an ohm.

A test was also made to determine the loss of oil by evaporation. The oil tanks of the switches were filled with fresh oil and the switches installed in an inclosure in which the temperature was maintained at 37° C. for 23 days and at 85° C. for 52 days of 24 hours each.

TEST RESULTS.

The first oil switch tested was a nonautomatic switch rated 50 amperes at 250 volts. This switch was operated mechanically 75,000 times at 100 amperes and 225 volts without causing an ignition of the gas surrounding the switch. On an average 11 operations were made per minute. Five complete sets of contacts were burned off during the test. The oil contained no free carbon at the beginning of the tests, but about 4.5 per cent at the end. During the evaporation test, described above, the weight of the oil in this switch decreased 2.2 per cent.

The second oil switch tested was a nonautomatic switch rated 100 amperes at 6,600 volts.[a] This switch was operated 75,000 times at 100 amperes and 225 volts without causing an ignition of the gas surrounding the switch. On an average 11 operations were made per

[a] Although this was the standard rating, the switch was offered for test as a 250-volt switch.

minute. During the test 3 complete sets of contacts were burned off. The proportion of free carbon in the oil increased from nothing to about 2.9 per cent. During the evaporation test the weight of the oil in this switch decreased 4.0 per cent.

The third oil switch tested was an automatic switch rated 100 amperes at 600 volts.[a] This switch was adjusted to release at 160 amperes and was operated as described above. On an average 12 operations were made per minute.

The gas surrounding the switch became ignited at operation 2,775. In the meantime the working of the switch had ejected a large amount of oil from the oil tank and the consequent lowering of the oil level had exposed the switch contacts so that the arc was formed at the surface of the oil. During the test two sets of contacts were completely burned up. The proportion of free carbon in the oil increased from nothing to about 3.9 per cent. During the evaporation test the weight of the oil in this switch decreased 3.9 per cent.

The fourth oil switch tested was a nonautomatic switch rated 100 amperes at 250 volts. This switch was operated 75,000 times at 100 amperes and 225 volts. On an average 11.5 operations were made per minute. The last 5,000 operations were made while the switch casing was open and surrounded by the most explosive mixture of the natural gas and air. The gas was not ignited in any test. The engineers who made these tests consider that if no ignition occurred during the last 5,000 tests, none would have occurred has gas been present during the 70,000 previous tests, and hence the test was equivalent to 75,000 operations in an explosive mixture of gas.

The switch contacts had to be renewed three times during the progress of the test. The oil was not changed from start to finish. The quantity of free carbon in the oil increased from nothing at the beginning of the test to 4.35 per cent at the end. No evaporation test was made with this switch, as its casing was practically air tight.

The fifth oil switch tested was a nonautomatic switch rated 100 amperes at 250 volts. This switch was operated 28,980 times at 100 amperes and 225 volts. On an average 8 operations were made per minute. On five different occasions the contacts were renewed completely or in part. The oil was not changed during the test, although each time that the contacts were renewed a small quantity of oil was added to compensate for the unavoidable loss incident to removing and replacing the switch mechanism. In none of the tests did the oil level fall low enough to expose the switch contacts, although as many as 10,000 operations were made with one set of contacts. This number of tests represents about three years' service on a basis of 10 operations per day and it is reasonable to assume that, before the lapse of so long a time, the oil in the switch casing will be replenished.

[a] Although this was the standard rating, the switch was offered for test as a 250-volt switch.

The last 6,221 operations were made while the switch casing was open and surrounded by the most explosive mixture of the natural gas and air. In no test was the gas ignited. This number of tests, for the reasons previously given, is considered as equivalent to 28,980 tests in an explosive mixture.

During the tests the free carbon in the oil increased from nothing to 1.06 per cent. No evaporation test was made with this switch because the casing was air tight.

DISCUSSION OF TEST RESULTS.

OIL SWITCHES.

The tests seem to indicate that the oil switches will not ignite explosive mixtures of gas under the conditions described as long as the switch contacts are covered with oil to a depth of 0.25 inch or more. This is best shown by the tests of the automatic oil switch in which the maximum instantaneous current was not far from 1,000 amperes. The tests also show that the oil is not lost rapidly by evaporation nor by many operations of the switches under rated current load and at a voltage as high as the probable underground voltage in places where explosive gas is likely to be present. The tests show that the switch contacts deteriorated more rapidly than the oil. Even in the case of the automatic switch that finally ignited gas, several sets of contacts were burned off before the oil level was so lowered that the gas was ignited.

It therefore seems reasonable to believe that oil switches will not ignite inflammable gas if they are designed with attention to the service that they are to perform and are inspected at reasonably frequent intervals.

EXPLOSION-PROOF SWITCHES.

The tests demonstrate the possibility of constructing an explosion-proof type of switch that will not ignite gas.

PERMISSIBLE SWITCHES.

The Bureau of Mines proposes to make tests to establish a list of electric switches permissible for use in mines where inflammable gas may be present. The conditions under which these tests will be made and the regulations governing the submission of switches for test will be published in a forthcoming bulletin.

PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF MINING.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.:

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs. Reprint of United States Geological Survey Bulletin 425.

BULLETIN 44. First national mine-safety demonstration, Pittsburgh, Pa., October 30 and 31, 1911, by H. M. Wilson and A. H. Fay, with a chapter on the explosion at the experimental mine, by G. S. Rice. 1912. 75 pp., 7 pls., 4 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Ilsley. 1913. 31 pp.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

TECHNICAL PAPER 18. Magazines and thaw houses for explosives, by Clarence Hall and S. P. Howell. 1912. 34 pp., 1 pl., 5 figs.

TECHNICAL PAPER 19. The factor of safety in mine electrical installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 21. The prevention of mine explosions; report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 12 pp. Reprint of United States Geological Survey Bulletin 369.

TECHNICAL PAPER 22. Electrical symbols for mine maps, by H. H. Clark. 1912. 11 pp., 8 figs.

TECHNICAL PAPER 24. Mine fires, a preliminary study, by G. S. Rice. 1912. 51 pp., 1 fig.

TECHNICAL PAPER 27. Monthly summary of coal-mine accidents in the United States, January to August, 1912, and statistics for 1910 and 1911, compiled by F. W. Horton. 1912. 24 pp.

TECHNICAL PAPER 28. Ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp.

TECHNICAL PAPER 29. Training with mine-rescue breathing apparatus, by J. W. Paul. 1912. 16 pp.

MINERS' CIRCULAR 3. Coal-dust explosions, by G. S. Rice. 1911. 22 pp.

MINERS' CIRCULAR 4. The use and care of mine-rescue breathing apparatus, by J. W. Paul. 1911. 24 pp., 5 figs.

MINERS' CIRCULAR 5. Electrical accidents in mines; their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 6. Permissible explosives tested prior to January 1, 1912, and precautions to be taken in their use, by Clarence Hall. 1912. 20 pp.

MINERS' CIRCULAR 9. Accidents from falls of roof and coal, by G. S. Rice. 1912. 16 pp.

MINERS' CIRCULAR 10. Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.

MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1912. 16 pp.

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